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# Build A Touch-Sensor Solution For Wet Environments

**A water-tolerant design offers a higher level of safety in white-goods applications, and it's cost-effective to boot.**

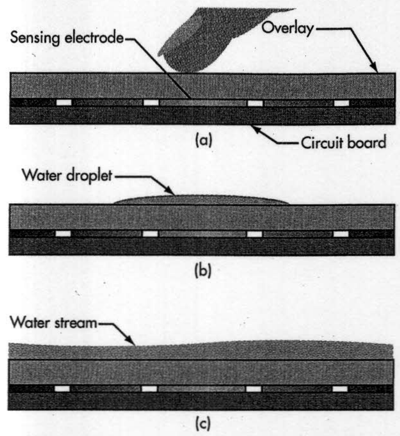
Capacitive touch sensors have made homes in scores of MP3 players and mobile phones. Of course, the mobile arena is no longer the only bastion for these devices. Today, sensor technology has literally exploded, expanding into many other product categories. However, this expansion produces a new set of design challenges.

White goods, such as electric ranges and dishwashers, is a product area that has spawned one of these new challenges: operation in a wet environment. To combat the problem, this article shows how to design water-tolerant capacitive touch sensors.

A waterproof design implies system performance that's totally immune to the effects of water. For a water-tolerant design, water levels encountered in normal operation don't interfere with sensor operation. Splatters and spills on the touch surface are tolerated, but total immersion is not. Water tolerance is a cost-effective solution for operation in a wet environment.

In a water-tolerant design, only the touch of a finger produces a signal large enough to register as a "touch." However, if a boiling pot overflows on an electric stove, and the touch surface is submerged in hot liquid, the water-tolerant sensor will be challenged to operate normally. By properly configuring the sensor array, the submersion can be detected, and the system would be subsequently alerted that an abnormal event has occurred.

The safest response to such an event is to turn off the burner until the spill can be cleaned up. In contrast, a waterproof design will continue normal operation after the spill. To turn off the burner, the user of a waterproof system needs to touch the sensor




1. Shown are cross-section views of the three categories of surface wetness: dry (a), droplet (b), and stream (c).

through a coating of hot liquid. If the liquid is too hot to touch, the burner stays on, and the pot keeps boiling, only making the situation worse.

The water-tolerant design, on the other hand, creates a system that turns itself off with a major spill. So, when comparing the two approaches for reacting to a spill of hot liquid, the water-tolerant design is obviously the safer and smarter choice.

## SURFACE WETNESS INTERACTION

Surface wetness is classified into three categories: dry, droplet, and stream *(Fig. 1)*. When liquid is sprayed or splashed onto a dry surface, surface tension causes the liquid to bead up, forming droplets. A water-tolerant design needs to operate normally when the surface is covered with droplets. For larger amounts of liquid, the droplets merge together and form a stream if set in motion or a puddle if the surface is at a low point.

Fingers are conductive, so they interact with the electric field that's set up around the touch sensors. Water is conductive, so it interacts with the same electric field when it lands in the active sensing area. This can lead to a report of a finger touch when water splashes onto the sensing surface, even when no finger is present.

Drops of water can produce the same signal level as a finger for a touch sensor that lacks any features for water tolerance *(Fig. 2)*. The "raw count" shown in the figure is the unfiltered output from the sensor. The "baseline" is a continuously updated estimate of the average raw count level when a finger isn't present. The baseline provides a reference point for determining when a finger is present on the sensing surface.

Fingers and water interact in a similar, but not identical, way with electric fields. However, enough difference exists between the two to develop techniques for discriminating between a touch and a spill.

On printed-circuit boards (PCBs) and flex circuits, a practical level of water tolerance is achievable by using a shield electrode and guard sensor. These electrodes add no material cost to the system, because they're incorporated into the same circuit-board layout as the touch sensors *(Fig. 3)*.

The purpose of the shield electrode is to set up an electric field pattern around the touch sensors that helps attenuate the effects of water.[1] The guard sensor detects abnormally high liquid levels so the system can react appropriately.

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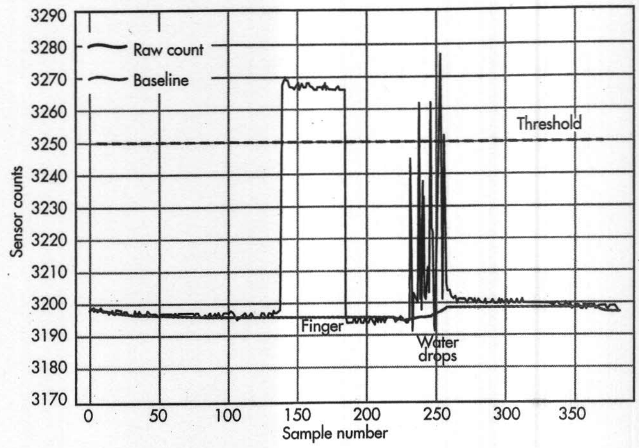


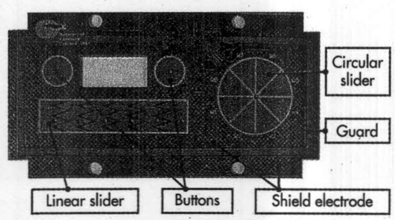

2. An example of a finger touch and drops of water both produce a signal that crosses the finger detection threshold for a sensor with no water tolerance.

## THE SHIELD ELECTRODE

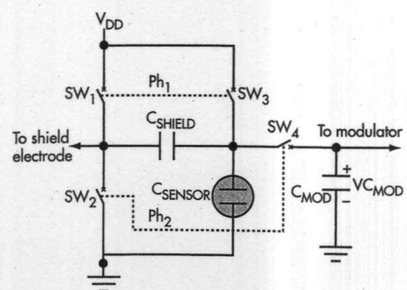
The shield electrode works by mirroring the voltage of the touch sensor on the shield. In practice, the shield electrode waveform only needs to approximate the shape and timing of the waveform on the touch sensor to be effective. In the CSD sensing method that runs on Cypress Semiconductor's PSoC chip, the shield is driven by internally switching the shield pin between $V_{DD}$ and ground *(Fig. 4)*.

The switches in the shield circuit are driven by a two-phase clock. In the first phase, the sensor capacitor, $C_{SENSOR}$, is charged up to $V_{DD}$, and the terminals of the parasitic capacitance associated with the shield are shorted together by switches $SW_1$ and $SW_3$.

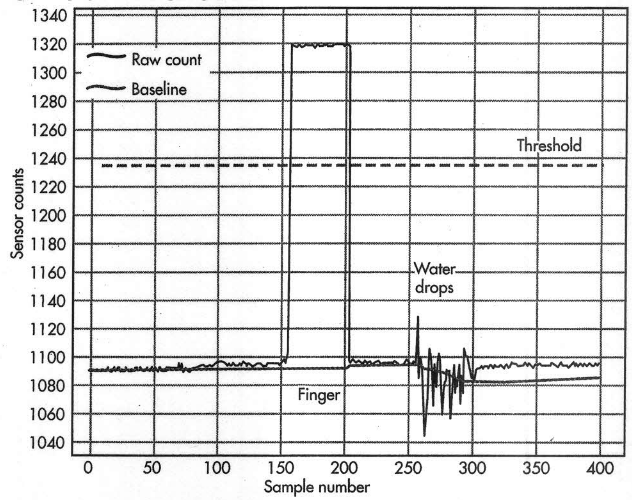
In the second phase, $C_{SENSOR}$ discharges into the capacitors $C_{MOD}$ and $C_{SHIELD}$, as well as into the modulator. The average current flowing through switch $SW_4$ sets the duty cycle of the modulator, which in turn will set the counter value of the CSD output.



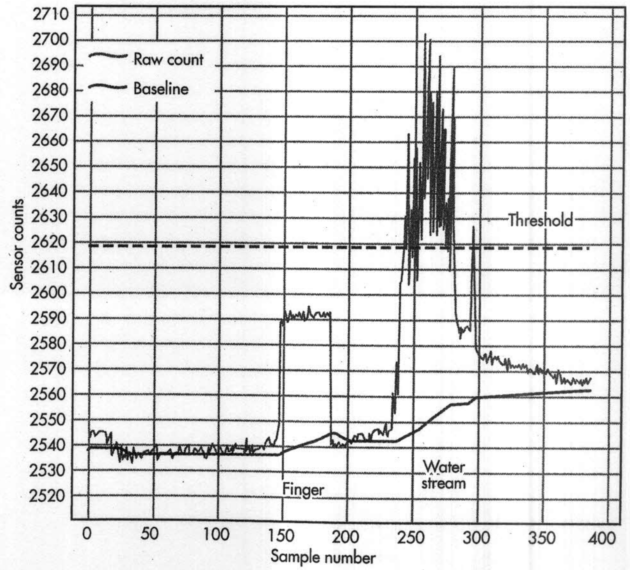

3. The shield electrode and guard sensor are added to the PCB layout to add water tolerance to standard touch sensors.




4. This shield electrode circuit is implemented with the CSD sensing method that runs on Cypress' PSoC chip.




5. For a sensor with a shield electrode, a finger touch produces a signal that crosses the finger detection threshold, which isn't the case when there are drops of water.




6. A finger touches the dry surface, and then a stream of water activates the guard sensor.



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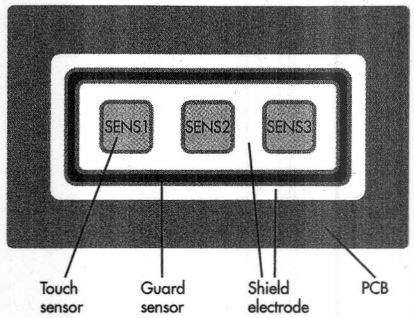
the modulator. It's interesting to note that with the shield in place, water and fingers produce opposite responses in the sensor output. Fingers cause an increase in counts, while water causes a decrease in counts *(Fig. 5)*.

## THE GUARD SENSOR

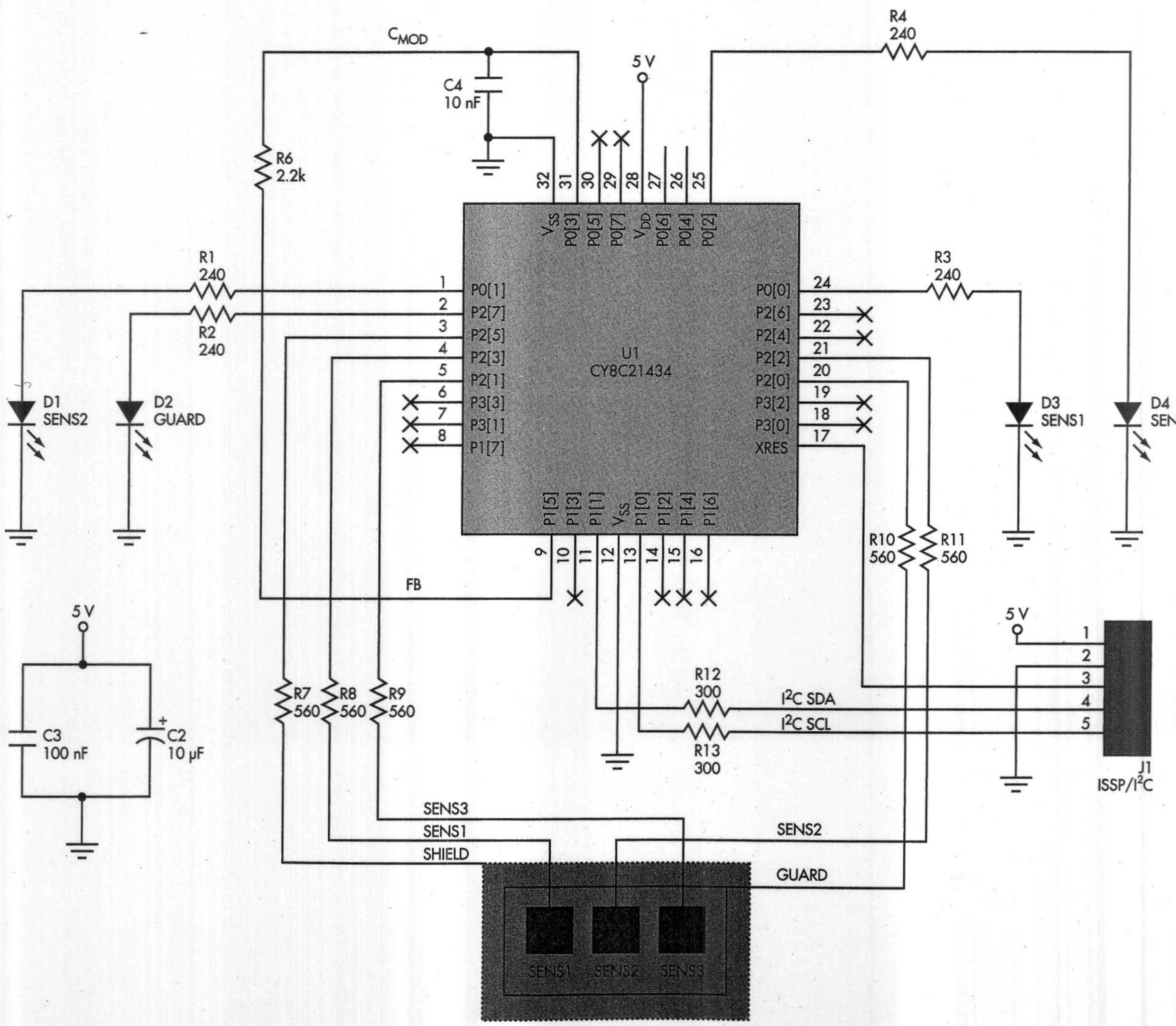
The guard sensor indicates that an abnormally large amount of water is on the sensing surface. The guard sensor is a special touch-sensor electrode that surrounds the other touch sensors. When touched with a finger, the sensor indicates the presence of the finger.

What makes the guard sensor special is that it produces a much larger signal with a stream than with a touch. To discriminate between the two, the shield electrode is grounded when sensor counts are acquired from the guard sensor. The counts for all other sensors are acquired with the shield voltage tracking the voltage on the sensor electrode, as described in the previous section.

Figure 6 shows the result of using this technique. A stream of water produces twice the signal than that from a finger. When the signal from the guard sensor crosses the threshold, the system is alerted that too much water is on the surface for normal operation. The designer can then decide the appropriate action in response to the spill.




**8. The touch sensors, shield electrode, and guard sensors are located on the top layer of the printed-circuit board (PCB), and all components are mounted on the bottom layer. The layout follows the guidelines for CapSense PCBs, which are described in a Cypress app note.**




7. This water-tolerant touch-sensing system is based on the CY8C21434 PSoC chip. It includes three touch sensors, a shield electrode, and a guard sensor.

### TEST CIRCUIT AND PCB

One example of a water-tolerant touch-sensing system is based on Cypress Semiconductor's CY8C21434 PSoC chip *(Fig. 7)*.[2] This design includes three touch sensors that are labeled SENS1, SENS2, and SENS3. In addition, the design includes a shield electrode and a guard sensor.

The touch sensors, the shield, and the guard sensor are all controlled by the PSoC. This microcontroller is also configured in firmware to drive a set of LEDs that indicate when a finger touch occurs. The ISSP/I$^2$C port supports the dual functions of programming and I$^2$C communication with a host computer. The CY8C21434 can support 20 sensor inputs when water-tolerant features are enabled. Unused sensor inputs can either be programmed for additional I/O functions or left unassigned.

Figure 8 shows the top view of the PCB for this application. The board layout follows the guidelines for CapSense PCBs, which are described in an application note from Cypress.[3]

### PUTTING IT ALL TOGETHER

The final step in system design is assembly of the PCB with the chassis and adhering the PCB to the protective overlay. The overlay material is a 2-mm thick acrylic sheet joined to the PCB with a thin layer of nonconductive adhesive film. When tested, performance figures showed that when the surface is covered with water droplets, and with the shield in place, finger response is around 10 times the signal produced by water droplets. Setting the finger detection threshold above the signal produced by the droplets, only finger touches are seen by the system, while the droplet signal is lost in the noise.

Testing also showed that when a stream of water covers the surface, both the touch sensors and guard sensor produce a large signal. The guard sensor produces a sixfold increase in signal with a stream of water compared to a crosstalk-induced signal level seen with water droplets and a dry surface. This big increase in the guard sensor's signal level makes it possible for the system to detect a big spill and react in a predetermined way. ED


### REFERENCE

1. Application Note AN42851, "Proximity Detection in the Presence of Metal Objects," Cypress Semiconductor
2. Application Note AN2398, "Capacitance Sensing—Waterproof Capacitance Sensing," Cypress Semiconductor
3. Application Note AN2292, "Capacitance Sensing—Layout Guidelines for PSoC CapSense," Cypress Semiconductor